The value of vigilance

Tenacious surveillance a key to progress in the eradication of polio

By **Diana Schoberg**

Several African countries are considered at high risk for a polio outbreak. But for many years, Malawi wasn't one of them.

The nation has a sound public health infrastructure, and its immunization rate is

good. The last time a child there had been paralyzed by polio was in 1992, decades before all countries on the continent were deemed polio-free. "Imagine how many children were born and grew up without knowing polio," says Jamal Ahmed, coordinator of the polio eradication program in the African region for the **World Health Organization.** So, when a child in Malawi tested positive for wild polio in February 2022, "it was a surprise," Ahmed says.

It was a similarly unwelcome surprise a few months later when Janell Routh saw an email from Kirsten St. George at the **Wadsworth Center,** the polio reference lab in New York State. The lab had identified a case of polio in an unvaccinated man living in Rockland County, about 30 miles north of Manhattan. "That was quite a shock," says Routh, a medical officer in the Division of Viral Diseases at the **U.S. Centers for Disease Control and Prevention.** "We never thought that we would see a case of paralytic polio in the United States."

So how did health workers discover polio in two countries long considered polio-free? And how can they be sure it's gone now? This process of searching for a disease is known as surveillance, something that Rotary has supported with $73.6 million in funding over the past five years. As the worldwide eradication of polio approaches, surveillance will play a pivotal role in ensuring that the world is truly polio-free.

Lab technicians take water samples at Bhalswa Lake in Delhi, India, to test for poliovirus. This process, known as environmental surveillance, helps officials search for asymptomatic cases that could signal an outbreak.

Alyce Henson

If executed as they should be, the fundamentals of conducting surveillance are relatively simple. "In public health, you only see what you look for," explains Stella Anyangwe, an End Polio Now coordinator from South Africa who previously served with WHO for 17 years. "If you don't look for something, you don't see it — though the fact you don't see it doesn't mean it doesn't exist. That's what surveillance does: You collect and analyze information and then interpret it."

One more indelicate detail: The way disease detectives surveil for polio is decidedly unglamorous. It turns out that a key to helping ensure a polio-free world is poop.

In November 2021, when the 3-year-old girl from a deprived area of Malawi's capital, Lilongwe, showed up at a hospital with paralysis in her right side, clinicians quickly diagnosed acute flaccid paralysis, a sudden onset of muscle weakness, usually in the limbs. AFP has many causes; polio is just one of them, and its occurrence is rare — one more reason why follow-up testing is essential.

By the numbers

- **145**
  active labs in the polio network
- **75**
  labs with the capacity for environmental surveillance
- **800**
  Sites worldwide conduct environmental surveillance
- **$73.6 million**
  in Rotary surveillance funding for calendar years 2018-22
- **85%**
  of countries in the WHO African region have an environmental surveillance system

Polio is spread through human waste (or, more rarely, through sneezing and coughing). It enters the body through the mouth, for example in contaminated food or water. The virus replicates in the gastrointestinal tract and is shed in feces. When doctors diagnose a patient with AFP, they send a stool sample to a polio reference lab to check for the virus. This is called AFP surveillance: looking for cases of AFP, polio's primary symptom, and then confirming, through the sample, whether the virus caused those cases.

Farrell Tobolowsky, a medical epidemiologist in the CDC's Global Immunization Division, uses an angling metaphor to describe AFP surveillance. "Never forget that net you cast when fishing," she says. "Polio is a fish you catch in that net."

In Malawi, clinicians obtained a stool sample from the girl, as is protocol. However, because it had been 30 years since the last case of polio in that country, the virus was far from anyone's mind. That January, the sample was sent to the nearest polio reference lab, in South Africa.

Lab workers put the sample on a cell culture to see if the poliovirus grew. When they sequenced the virus, they realized it was wild polio type 1. The sample was sent on to a specialized lab at the CDC in Atlanta, where additional testing confirmed the finding and determined that the sample's genetic sequence was linked to a transmission chain last seen in Pakistan's Sindh province in October 2019.

The genes act as a sort of "molecular clock," explains Ousmane Diop, coordinator of WHO's Global Polio Laboratory Network. As the poliovirus is transmitted, it mutates, at a rate of about nine mutations per year. Counting the number of mutations within the sample, scientists could determine how long the virus had been circulating.

Ahmed says the sample's genetic sequence showed the virus had been imported into the region. "It had diverged enough that it was clear it had been circulating two years or more," he says.

On the watch for polio

Surveillance for acute flaccid paralysis is the gold standard for detecting poliomyelitis cases. The four steps of surveillance are:

1. Finding children with AFP and reporting cases

2. Transporting stool samples for analysis

3 Isolating and identifying poliovirus in the laboratory

4 Mapping the virus to determine the origin of the strain

Source: Global Polio Eradication Initiative

As in Malawi, doctors in the United States weren't looking for polio. The last case of wild polio contracted there was in 1979. But in 2014, they began to see children with similar symptoms. "If this was 50 years ago, we would have considered them polio cases," Routh says. "But since polio had been eliminated, what was causing this?" Scientists have found that other viruses in the same family as the poliovirus can cause a polio-like illness, and one called EV-D68 was likely behind outbreaks in 2014, 2016, and 2018.

In June 2022, when the unvaccinated 20-year-old man in New York State went to the emergency room with back and stomach pain, neck stiffness, mild fever, and weakness in both legs, clinicians were looking for that polio-like illness, which is called acute flaccid myelitis. With the onset of summer, a common time for AFM to surface, New York had sent out an alert to clinicians asking them to keep an eye out for patients with any sudden muscle weakness.

With AFM on their minds, doctors, observing the man's lack of reflexes and leg strength, gathered stool and other samples to test for AFM. To everyone's surprise, the stool sample tested positive for poliovirus. Genetic sequencing found it to be variant poliovirus type 2 related to strains circulating in London and Jerusalem. Multiple outbreaks of this variant poliovirus are circulating in underimmunized communities around the world.

"It was amazing to see all the work we'd done since 2014 to set up [the AFM] surveillance system come to fruition," Routh says, "and be able to capture the first [polio] case in the U.S. in a very long time."

In Pakistan, one of two remaining polio endemic countries, environmental surveillance plays an important role in detecting the virus. As of June 2023, the country had 114 sewage collection sites; 1 percent of the samples tested positive for the virus in the first six months of the year.

World Health Organization

With the assumption that polio had been circulating in Africa for two years, WHO, CDC, and other international partners were in full response mode within days of confirming the wild polio case in Malawi. Their first goal was to prepare for the mass vaccination of more than 33 million children in Malawi and the nearby countries of Mozambique, Tanzania, Zambia, and Zimbabwe.

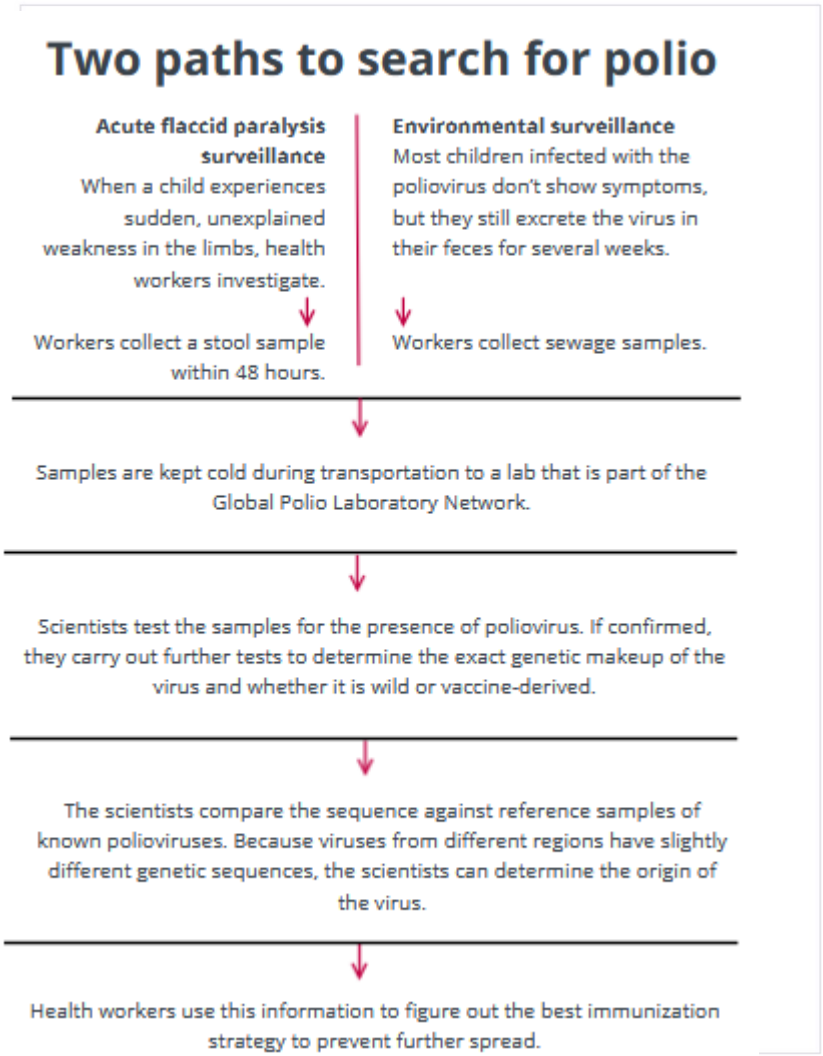
Simultaneously, officials educated workers across the medical system in those five countries, and health workers watched for polio symptoms as they traveled from house to house to vaccinate children. Through this enhanced surveillance, eight additional children and adolescents in Mozambique who had been paralyzed by polio were identified. "You can imagine the pandemonium that set in," says Anyangwe, a member of the Rotary Club of Pretoria, South Africa, who went to Mozambique to participate in a review of the response by the **Global Polio Eradication Initiative.**

The Mozambique cases were all in the country's northwestern Tete province, which officials now believe was the outbreak's epicenter. "We believe the first importation came in Mozambique," Diop explains, "and the one detected in Malawi may have

been detected because surveillance is more sensitive in Malawi."

In the United States, officials leapt into action as well, working under the assumption that one case of type 2 polio could mean thousands of mild or asymptomatic infections. The CDC held a webinar for doctors and increased vigilance around sudden muscle weakness. Health officials worked to boost vaccination rates; in Rockland County, where the man diagnosed with polio lived, only 60 percent of 2-year-olds had received the recommended three polio vaccine doses, including one postal code where only 37 percent of children that age were fully immunized. The national average is 93 percent.

To get a sense of how long the outbreak had been going on and how far it had spread, the CDC turned to another indispensable device in its toolkit: environmental surveillance.



Because the world is nearing the eradication of polio, very few children are paralyzed by the disease every year. But those children are representative of thousands of asymptomatic infections. Acute flaccid paralysis surveillance catches

the paralytic cases. But how do we find the others?

Once again, it comes back to fecal samples. Scientists employ the same process used when testing a paralyzed child's stool, but instead, they analyze samples from the local sewage system. This process of environmental surveillance helps them survey an entire population of children rather than just one. Using Tobolowsky's fishing net analogy, environmental surveillance casts a wider net by looking for the virus in sewage.

As far back as the ancient Greeks, people blamed sewage — or rather, the vapors it exuded — for disease transmission. The idea that wastewater itself was the culprit goes back to England in the mid-19th century. Typhoid was isolated from wastewater in 1928, and, by 1939, scientists determined that wastewater could be used as an indicator of poliovirus activity.

In 2000, the GPEI began looking for the poliovirus in sewage samples in Egypt, where polio was still endemic. The effort contributed to the eradication of wild poliovirus there, which led the GPEI to roll out environmental surveillance in other polio-endemic countries starting in 2009; it was later expanded to additional countries. Other countries also perform their own wastewater surveillance outside of the GPEI. Altogether, Diop says, environmental surveillance is conducted at around 800 sites worldwide.

Health workers take a wastewater sample at a sewage site near Uzhhorod, Ukraine. Two children were

paralyzed by variant poliovirus type 2 in the country in 2021; environmental surveillance can help officials have confidence that the outbreak is truly over.

World Health Organization

In countries with good sewer systems, health officials collect samples of raw untreated sewage that is on its way to the treatment plant. But in reality, the areas with the highest risk for polio often have poor sanitation. In those instances, as health officials try to determine exactly where to take their samples, they look for other telltale indicators, such as places with an underdeveloped socioeconomic environment, a high level of migrants and population movement, and a history of outbreaks of polio and other diseases.

Having made that determination, health officials zero in by using census statistics and satellite imagery from those specific areas, as well as topographic maps to see where sewage flows from the highest points to the lowest. "Usually an appropriate site is one with good flow, not something stagnant," says Ahmed. "We try to target the morning on the assumption that most people use the toilet then."

In areas that have typically been inaccessible to polio workers, sanitation workers tend to have a level of trust with communities; as Diop explains, nobody wants sewage draining in front of their home. Because of that, those sanitation workers can usually get the necessary samples.

In February 2022, when Malawi's polio case was confirmed, the country had been on the GPEI's expansion list for environmental surveillance, and a team had already begun preliminary work. "The minute the case was identified, we had two or three surveillance officers going from city to city assessing appropriate collection sites," Ahmed says. "I think within four days of the declaration of the outbreak, we had collected our initial environmental surveillance samples from one of the sites in Lilongwe. Within a month, we had eight or nine sites across the country." No samples in Malawi have come back positive for wild poliovirus.

Environmental surveillance was also ramped up in surrounding countries, including in the outbreak's epicenter, Tete province in Mozambique. There, however, health officers struggled to find quality environmental surveillance sites and have been unable to detect wild poliovirus in the wastewater. "The AFP surveillance system was the most valuable," Ahmed says.

Once identified, a positive sample can provide useful information. In Botswana, for example, variant poliovirus type 2 was identified last year through environmental sampling, and officials were able to launch two rounds of immunizations, stopping

the disease before it paralyzed anybody. But a negative sample is not as definitive as a positive sample. Yes, a negative result could mean the disease is not present, but it could also mean the sample was poor or simply taken on the wrong day. A sample is just a snapshot in time, Diop insists. "It adds value, but it's not a panacea to detect all poliovirus," he says. "Environmental surveillance can only be a supplement for AFP surveillance, which is still the gold standard."

In the United States, health officials also turned to wastewater sampling to gauge the extent of the spread of the variant poliovirus, a task made less onerous since the pandemic.

After studies demonstrated that the COVID-19 virus could be traced in wastewater, the CDC established the National Wastewater Surveillance System in 2020 to detect surging infections. As of June 2023, more than 1,400 sites around the country performed wastewater surveillance for the coronavirus, representing 40 percent of the American public. The sites regularly collect data and submit it to the CDC.

Researchers used these samples gathered for COVID-19 surveillance to look back in time after health officials identified the New York polio case. "New York State had been testing for COVID and storing specimens," Routh says. "We were able to pull specimens off the shelf and test retrospectively." The man paralyzed by polio developed weakness in June; officials looked at samples collected in Rockland County and a neighboring county in May and April and found some positive for poliovirus. This signaled the virus had been circulating for weeks before the patient arrived at the hospital, which set off, as the detection had in Malawi, a drive to increase polio vaccinations among unvaccinated children and greater vigilance for polio symptoms.

Health officials then expanded their search, looking in New York City, where people from the patient's community often traveled; other nearby counties; and places with similar populations in Connecticut and New Jersey, states bordering New York. While there were no positive samples in the other two states, researchers consistently detected polio in sewage samples in New York until October 2022, when detections abruptly fell off (polio is statistically more of a summer disease in temperate climates). There have been no positive wastewater samples since late February. The CDC has since made plans to expand testing to several other communities in other states with lower vaccination rates.

"We're really grateful," Routh says. "We were nervous moving into summer that there might be a flare of poliovirus in the wastewater, or we would see a reimportation of poliovirus from another county experiencing an ongoing

outbreak. We're keeping our fingers crossed."

Ahmed too is watching and waiting to see whether the wild polio outbreak in Africa has been contained. "Polio is a very tricky virus," he says. "It can circulate for quite a while without detection. We always say that it takes a combination of good surveillance and time."

A worker from the Ministry of Health in North Darfur, Sudan, conducts environmental sampling for polio outside of a health facility in al-Fasher. Officials work to maintain the level of surveillance required to rapidly detect any new emergence of the virus.

World Health Organization

Researchers are working to increase the sensitivity of the testing to detect polio in sewage samples even if the transmission rate is very low — in effect, making the grid of the fishing net so fine that no cases can slip through. "This will be important even for post-certification," Diop says, "to be sure we're not missing any poliovirus."

Continued consistent testing in high-risk areas will be important too, because one negative sample could just mean an off day. Consistently negative tests will increase officials' confidence that polio is truly gone.

With a three-decade track record, the GPEI's lab network — both the people and

the physical lab infrastructure — proved pivotal for COVID-19 surveillance. Experts in the polio lab network helped set up national processes for testing for the coronavirus, and lab workers pitched in on efforts to detect it. "[We] have the skills," Ahmed says. "We're also benefiting from the infrastructure that was expanded because of COVID with a higher number of people who have the know-how to do sequencing. It's a win-win scenario for public health in Africa when it comes to the lab network."

This expanded wastewater surveillance network around the globe has a vast potential for the future. "The uses are endless," Routh says. "I'm interested in using it for influenza. Could we predict the strains the United States could be seeing in their influenza season and be able to adapt vaccines more quickly?" In 2022, U.S. researchers tested sewage to track the spread of mpox, the virus previously known as monkeypox. And wastewater can be used for everything from monitoring opioid use to predicting obesity rates in a community to watching for drug-resistant tuberculosis strains, enabling a more rapid response.

The future of polio eradication is surveillance, and wastewater-based epidemiology will be a key tool in those monitoring efforts. In the future, it might also play a pivotal role as society confronts other public health issues — which means that the investments Rotary has made in surveillance will continue to pay dividends for years to come.

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